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VENUS, RECENT PHYSICAL DATA FOR

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L.D. Kaplan paper

VENUS, RECENT PHYSICAL DATA FOR. The planet Venus was the subject of a formidable array of scientific investigations during the 1962 inferior conjunction, including the measurements during the successful flight of Mariner II. The results of these investigations have greatly increased our knowledge of our sister planet, but many questions remain unanswered.

The Mariner II microwave measurements showed unambiguously that limb darkening was present at 19 mm wave-length and therefore that the origin of the high thermal emission at cm wave-lengths is at or near the surface of the planet. After eliminating the limb darkening and dividing the resulting brightness temperature by an assumed surface emissivity derived from earth-based radar measurements of reflectivity, a fairly uniform surface temperature of about 700°K is obtained.

The surface origin of the high thermal emission was further supported by the discovery, prior to the Mariner encounter, that the low-frequency branches of the Venus bands of CO_2 had double maxima, with positions corresponding to 300°K and 700°K . The appearance of the double maxima suggested that sunlight is reflected both by a cloud layer or layers with a definite base at an altitude corresponding to an ambient temperature somewhat in excess of 300°K , and by the surface. Further evidence for this interpretation was the discovery that the lines near the 700°K maximum were considerably broader than those near the 300°K maximum. The line-breadths corresponded to a pressure of several atmospheres, and indicated a surface pressure of the order of 10 atmospheres.



The Mariner II infrared measurements also showed definite and substantial limb darkening in both the transparent (8.4μ) channel and the CO_2 (10.4μ) channel. Within calibration uncertainties, the brightness temperatures were the same for both wavelengths at each location on the planet, varying from about 240°K in the vertical to about 220°K near the limbs. The approximate equality of the brightness temperatures at both wavelengths indicated that all temperatures read were cloud temperatures and that the cloud top was at a temperature below 220°K . The fact that one can "see" down to an average temperature of 240°K implies that the clouds were diffuse, and the fact that no radiation from the hot surface got through implies that they were very thick, in agreement with the discussion above.

From the Regulus occultation data and the new surface and cloud top data, the radius of the solid planet can be estimated by assuming constant lapse-rates of temperature between the surface and cloud top and between the cloud top and occultation level. The result, using a CO_2 abundance of 10 per cent derived from spectroscopic measurements, is 6010 ± 30 km. This corresponds to a value of 900 cm/sec^{-2} for surface gravity, consistent with the mass of the planet ($4.87 \times 10^{27} \text{ g}$) as determined from the Mariner II trajectory measurements.

Rotation rates were obtained from independent and completely different active radar measurements using the Goldstone antenna. These included range-gated spectra of the reflection of modulated signals from isolated concentric zones on the planet, and the high resolution spectra of the reflection of a continuous wave signal. The continuous

wave spectra showed a detail, suggesting a surface feature, which appeared to move slowly across the planetary disk. The results of both experiments indicated a sidereal rotation of about 250 days in the retrograde sense, with the axis nearly perpendicular to the orbit of Venus. The retrograde rotation was further supported by the observation of a phase lag in the results of passive radar measurements, consistent with the results obtained by the active measurements. The passive measurements showed an increase in brightness temperature with phase angle, indicating a higher bright-side temperature.

Other evidence for surface features was obtained from the observation of a cold area in the Mariner infrared measurements and from measurements in the $8\text{-}14\mu$ window at Mt. Palomar. From radar reflectivity data, the reflectivity was estimated to be about 10 per cent and the dielectric constant about 4, suggesting that Venus has a dry, sandy, or rocky surface. From the same measurements, the rms slope is estimated to be between 4 and 7 degrees.

Water vapour has been recently detected with a high degree of certainty from balloon measurements during the dichotomy preceding the 1964 conjunction. The amount depends on the location of the effective reflecting layers, but is of the order of 10^{-2} g/cm^2 . There is also evidence that oxygen has been detected through measurements of doppler-shifted lines from the Crimean Observatory.

The presence of oxygen and water would eliminate several atomic possibilities for the cloud composition. The small amount

of water eliminates it as a cloud component except at the very top layers and the cloud temperatures are high enough to definitely exclude carbon dioxide. The definite cloud base indicated by the double-maxima in the low frequency wings of Venus bands of CO_2 suggests that the clouds are condensation products, however. An attractive possibility is that the clouds are mostly composed of organic compounds, many of which have sufficiently high condensation or polymerization temperatures. About one meter STP of almost any gaseous compound containing a C-H bond would be sufficient to close a spectral window around 3.5μ , which would otherwise allow more radiation to escape from the surface than can possibly be compensated by incoming sunlight. The remaining spectra is probably opaque enough through absorption by hot CO_2 and N_2 to account for the high surface temperature by a very effective greenhouse effect.

Most of the newly determined properties of Venus described above are listed in the following table.

Table. Newly Determined Properties of Venus

Radius (solid surface)	$6010 \pm 30 \text{ km}$
Mass	$4.870 \times 10^{27} \text{ g}$
Density	5.36 g cm^{-3}
Surface gravity	900 cm sec^{-2}
Rotation period	$250 \pm 40 \text{ days retrograde}$
Surface pressure	$10 \pm 3 \text{ bars}$
Surface temperature	$700 \pm 150^\circ \text{K}$
Cloud top temperature	$< 200^\circ \text{K}$

Compositional estimates are not included in the table, as they are critically dependent on the relative reflectivity as a function of altitude, which is still very poorly understood.

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